A51N-0269

Connections between Stratospheric Pollution and the Asian Summer Monsoon

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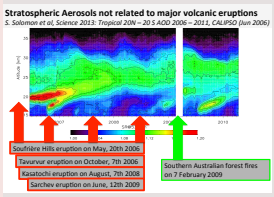
Motivation:

The Asian Summer Monsoon circulation can influences upper tropospheric and stratospheric aerosol concentrations (1). Further, stratospheric background aerosol concentrations have increased since 2000 (2). This leads to the question: **Does significant amounts of non-volcanic aerosol reach the stratosphere, and accumulate?**



(2) Calipso plot showing impact of smaller volcanic eruptions on stratospheric AOD.

Conclusions:

①Models do simulate the aerosol layer at the tropopause level associated with the Asian Monsoon season (ATAL).
②Both models explain the ATAL to be composed of mostly natural aerosols, and thus do not see any accumulation of significant amounts of 'anthropogenic pollution' in the stratosphere.
③One aerosol scheme explains ATAL to be composed predominately of desert dust, the second scheme predicts secondary organic aerosols to be the main constituent.
④ The models explain the increased trend since 2000 with smaller volcanic eruptions that occurred since the last major eruption in 1991.
⑤Next steps will include 3D validation, and experiments using the model with improved stratospheric dynamic.

Model:

The climate model used in this study is the NASA GISS climate model, ModelE2 with 2° by 2.5° horizontal resolution and 40 vertical layers, having the model top at 0.1hPa (3). We use two aerosol schemes: **MATRIX** which resolves aerosol microphysics (4) and **OMA** which includes secondary OA formation (5).

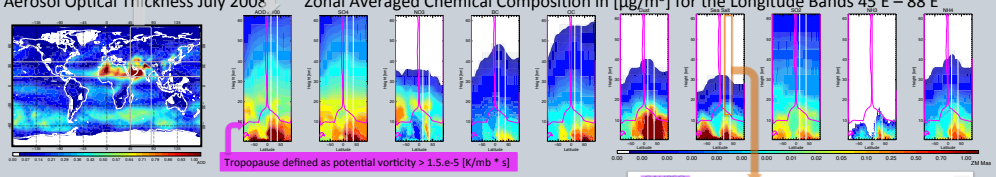
References:
(1) Vernier et al, 2015, JGR
(2) Solomon et al, 2011, Science
(3) Schmidt et al, 2014, JGR
(4) Bauer et al, 2008, ACP
(5) Tsigaridis et al, 2013, ACP

Does the model simulate the Asian Tropopause aerosol layer?

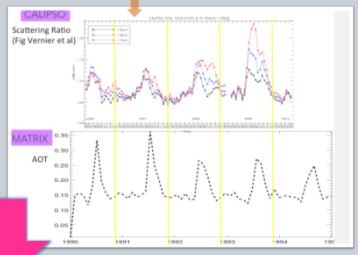
GISS-modelE-MATRIX

Aerosol Optical Thickness July 2008

Zonal Averaged Chemical Composition in [µg/m^3] for the Longitude Bands 45 E – 88 E



Tropopause defined as potential vorticity > 1.5.e-5 [K/mb * s]

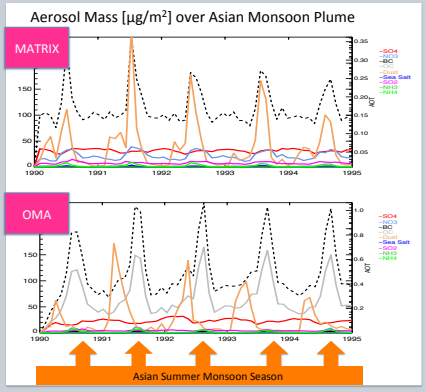


- The model shows high AOD concentrations over India and its neighboring states during the Asian Summer Monson Season .
- A small fraction of the high tropospheric gas and aerosol concentrations reaches the stratosphere during the Monsoon season.
- The comparison between models AOD and CALIPSO back scatter shows that the model simulates the ATAL in the correct season.
- **The largest mass concentrations, and thus explaining most of the increased Stratospheric AOD (SAOD) signal, is caused by natural aerosols.**
- **Sulfate aerosols provide the largest 'back ground' concentration in the Stratosphere even during years without major volcanic eruptions.**

What type of Aerosol reaches the Stratosphere via the Asian Monsoon?

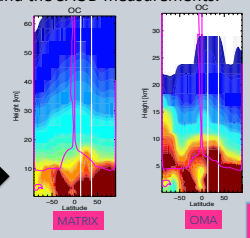
GISS-modelE-MATRIX vs. GISS-modelE-OMA

Aerosol Mass [µg/m^2] over Asian Monsoon Plume



- **MATRIX:** The largest mass concentrations, and thus explaining most of the increased Stratospheric AOD (SAOD) signal, is caused by desert dust aerosols.
- **OMA:** Organic aerosols (OA) are calculated to significantly contribute to the SAOD. Dust, the other possible contributor to SAOD, is calculated to peak earlier in the year, contrary to the MATRIX simulations. Differences in atmospheric dynamics, precipitation patterns and wind speed at surface can contribute to this discrepancy, but also the calculated dust size distribution.

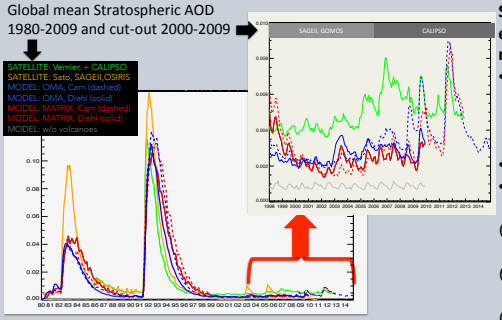
The correction of the dust seasonality in OMA, or the inclusion of semi-volatile organics in MATRIX, can independently help explain the discrepancy between the model and the SAOD measurements.



Secondary Organic Aerosol Formation:
Semi-volatile Organics that have remained in the gas phase close to surface can condense much easier at the upper layers of the troposphere due to lower temperatures, because the volatility of SOA is a strong function of temperature. Close to the tropopause, where the temperature is extremely low, virtually all semi-volatile organics condense. This leads to SOA formation at the UTLS region due to physical, not chemical processes.

Does Pollution Accumulate in the Stratosphere?

Global mean Stratospheric AOD
1980-2009 and cut-out 2000-2009



Stratospheric AOD: Model simulations, including (red, blue) and excluding (grey) volcanic SO_2 emissions, and two Satellite retrieved datasets by Vernier (green) and Sato (orange).

- Stratospheric AOD since 1980 is dominated by the two major eruptions, El Chichon (1982) and Mt Pinatubo (1991). The models deviation is explained by too fast polar transport of the Stratospheric plume.
- The satellite data show an increasing trend since 2000.
- The model without volcanic emissions doesn't show any trend.

Leading to the following conclusions:

①The model doesn't show any accumulation of pollution in the Stratosphere.
②SAOD variations since 2000 are explained by smaller volcanic eruptions.
③No anthropogenic aerosol contribute to the trend in SAOD